2007

Early flotant establishment and growth dynamics in a nutrient amended wetland in the lower Mississippi River delta

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EARLY FLOTANT ESTABLISHMENT AND GROWTH DYNAMICS IN A NUTRIENT AMENDED WETLAND IN THE LOWER MISSISSIPPI RIVER DELTA

A Thesis

Submitted to the Graduate Faculty of the
Louisiana State University and
Agricultural and Mechanical College
in partial fulfillment of the
requirements for the degree of
Master of Science
in
The Department of Oceanography and Coastal Sciences

by
Caleb W. Izdepski
B.S., Louisiana State University 2003
December 2007

ACKNOWLEDGEMENTS

My greatest thanks to my father for the confidence to move forward academically. Dr. Day for his guidance and support and for the opportunity to experience broadly the coastal landscape as well as art and literature. I regard his advice, along with my fathers, as the most significant influences on my life in these recent years. John has had the opportunity to teach sixty students before me and I am only just beginning to understand the gratitude that all of us owe. Dr. Charles Sasser and Dr. Richard Keim, both experts in the system I've taken these years to understand. Dr. Brian Fry, I'm am unable to speak with the man without gaining an understanding of something I am likely to never have considered.   Jason Day and Dr. Rob Lane who have found both success and great enjoyment in their work and this had an impact on my studies in a broad sense. And finally Colleen Morgan for showing me there are people who love our coast and our culture and will always fight to hold it. This work was funded in part by a grant from the Coypu Foundation.

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ABSTRACT

Nutrient dynamics and seasonal marsh growth were examined in a newly formed *Panicum virgatum* floating marsh at Thibodaux LA. The floating marsh formed in a cleared area of forested wetland receiving secondarily treated effluent. Net Areal Primary Productivity (NAPP), total belowground biomass, NO_3, and $\delta^{15}N$ ratios varied significantly ($P < 0.05$) along a 75m marsh transect while mean $\delta^{13}C$ varied between plant species. The upland end of the transect had the highest NAPP (3876 g $m^{-2}y^{-1}$), total belowground biomass (4079.0 ± 298.5 g m^{-2}), and mean NO_3 (5.4 ± 2.9 mg l^{-1}). The mean floating-marsh $\delta^{15}N$ of *H. umbellata* was less enriched at 0-75 m (9.69 ± 1.9 ‰) compared to 100-200 m (20.99 ± 3.8‰). The $\delta^{13}C$ of the belowground peat mat of the floating marsh was similar to *P. virgatum* but not *H. umbellata*, indicating that P. virgatum was forming the mat. There was a significant decrease in NAPP, total belowground biomass, NO_3 and $\delta^{15}N$ enrichment across the 75 m transect. Nutrient availability affected NAPP and $\delta^{15}N$. Floating marsh NAPP in the 0-45 m was greater than most reported values for floating marsh. These results suggest that nutrient rich freshwater can promote restoration of floating marshes.

1 INTRODUCTION

1.1 Land Loss in the Mississippi Delta

The Mississippi delta was formed by a series of overlapping delta lobes over the last 6-8 thousand years (Day et al. 2007). Historically, annual spring floods resulted in a net aerial increase of the delta over the last 6000 years. Major wetland systems formed in interdistributary basins between active and older natural levee ridges formed by the river. These wetlands ranged from saline near the coast to fresh in the upper parts of these basins. Extensive floating marshes formed in fresh and low salinity areas where there was reduced mineral sedimentation, low physical energy, high subsidence, and increased peat production (Russell 1942, O'Neil 1949, Sasser et al. 2007). Beginning soon after the founding of New Orleans in 1717, the delta plain was progressively isolated from the river by levees and distributary closures (Day et al. 2007). These changes led to high rates of coastal wetland loss in the 20th century due to lack of river input, subsidence, and saltwater intrusion (Day et al. 2000, 2007; Penland and Ramsey 1990) leading to plant stress and death (Mendelssohn and Morris 2000).

The major approach to delta restoration is the reintroduction of river water to the delta plain via river diversions (USACOE and LADNR 2003, Boesch et al. 1994, 2006, Day et al. 2007). But there are other important sources of freshwater, nutrients, and sediments to the coastal zone. Point and non-point sources of freshwater can also be useful in coastal restoration (e.g., Day et al. 2004). Day et al. (1992) proposed a restoration strategy that adding nutrient rich secondarily treated municipal effluent to hydrologically isolated, subsiding wetlands could promote vertical accretion through increased organic matter production and deposition. Breaux and Day (1994) further suggested the addition of sediments and nutrients in rapidly subsiding areas could offset accretion deficits, improve effluent water quality, and result in substantial economic savings compared to conventional water treatment.

One place where treated effluents are discharged directly to subsiding wetlands is in Thibodaux, Louisiana. High rates of local subsidence and tree clearing of a power line right-of-way transformed several hectares of forested wetland to shallow open water. Discharge of treated effluent into this wetland began in 1992. By 2002, *Panicum virgatum* became established along the wetland boundary where effluent was discharged to the shallow open water area and in 2003 began to extend into the wetland. *P. virgatum* has not been reported as an important component of floating marshes in Louisiana, however within four years of first establishment at Thibodaux, a highly productive marsh developed with floating marsh characteristics. In this thesis, I investigated the dynamics of this floating marsh.

1.2 Floating Marsh Ecology

Floating marshes are wetlands of emergent vegetation with a mat of live roots and associated dead and decomposing organic material and mineral sediments, that moves vertically as ambient water levels rise and fall (Sasser 1994). In contrast to attached marsh, a floating marsh can avoid the flooding stress that is commonly associated with hydrologic impoundment or high subsidence and sea level rise. Floating marshes track ambient water level, rising and falling with tides and seasonal flooding (Sasser et al. 2007). These are live plant communities that create and maintain a floating substrate of live roots and decomposing plant material and once established are often co-inhabited by other wetland plants (figure 1.1). The nutrient requirements of floating marsh are partially self regulated. DeLaune et al. (1986) showed as much as 80% of the living plants; mineral nutrient requirements are recycled from the peat. The marsh becomes nearly selfsufficient; existing in full sunlight, its water supply remains nearly constant, and its nutrient requirements are nearly all met by recycling from the substrate (Sasser et al, 1994).

Floating marshes are mostly restricted to areas with relatively low hydrologic energy and low salt stress (Sasser et al. 1995, Holm et al. 2000). Currents and wave energy facilitate mat erosion while salt stress may change the plant community to one that is not conductive to mat flotation and cause mat decomposition. Another stress to floating marshes is nutria (*Myocastor coypus*) grazing (Sasser et al. 2007). The thin mat flotant types are of lower productivity and thought to be a deteriorated form of flotant. Thus, a continuing concern for floating marshes in coastal Louisiana is their potential for rapid deterioration. Without an understanding of the historic multiple stresses inherent to the delta cycle (Sasser et al. 2007), proper conservation and restoration are not possible. Once a floating marsh is stressed, increasing physical energy can exacerbate its deterioration.

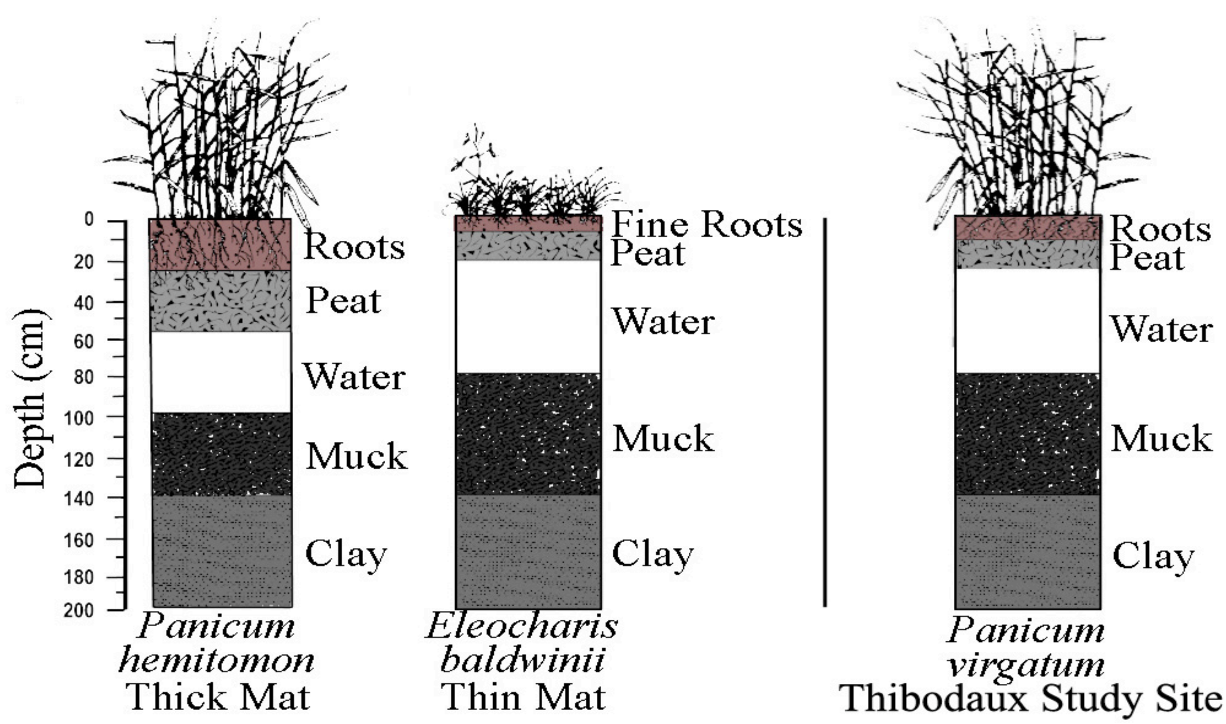

Figure 1.1 - Thick and thin mat floating marsh profiles and a generalized profile for the Thibodaux treatment wetland (Modified from: Sasser 1994).

If a floating marsh is sustainable, it can continue to expand in thickness and aerial coverage, and potentially become an attached marsh. My objective was to follow seasonal growth dynamics of the floating marsh community at Thibodaux in relation to nutrient dynamics within the wetland. The central hypothesis was that nutrient and freshwater additions stimulate productivity and therefore sustainability of the marsh. I hypothesized that productivity would be highest near the outfall and decrease with distance. Also peat accumulation, and therefore floating mat thickness, would be greatest near the outfall and thin with distance. As more assimilation wetlands are established, understanding the factors that lead to flotant establishment and sustainability will aid in management decisions where secondary freshwater sources are utilized as part of a broader restoration strategy.

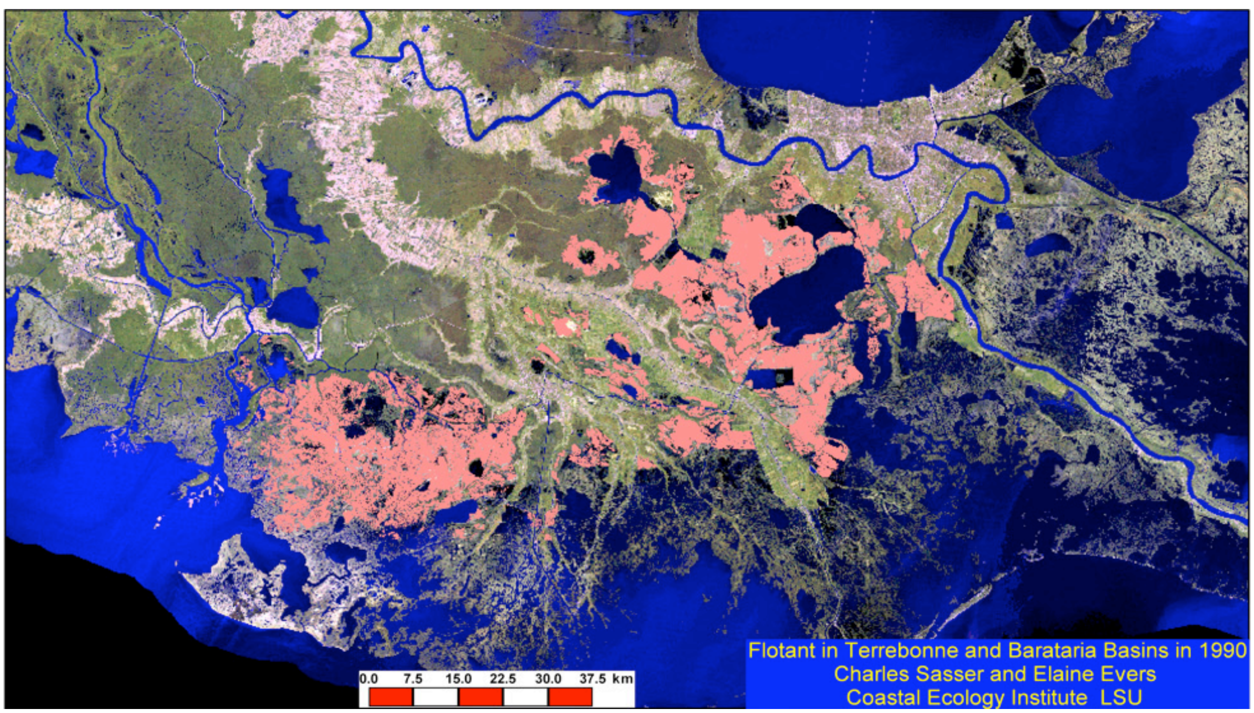

Figure 1.2 – Distribution of freshwater marshes in the Barataria-Terrebonne Basins (Evers et al, 1992)

2 MATERIALS AND METHODS

2.1 Site Description

The study was carried out at the Pointe au Chene forested wetland in south Louisiana. This site is a subsiding cypress-tupelo swamp on the backslope of Bayou Lafourche, a former course of the Mississippi River, 10km southwest of Thibodaux, Louisiana (Figure 2.1). From the time of settlement by the French in the early eighteenth century to the its closure in 1904, Bayou Lafourche carried an average of 12% of the Mississippi River, or about 1,100 m^3s^{-1} (EPA 1998). The study site is a 231 ha semi-isolated, continuously flooded, forested wetland adjacent to the Terrebone-Lafourche drainage canal. The soils are classified as Fausse (very fine, montmorillonitic, nonacid, thermic typic fluvaquents) and effectively restrict groundwater exchange (Zhang et al, 2000). Over the second half of the 20^{th} century the study area experienced increased flooding due to subsidence and isolation from outside freshwater inputs and a transition from bottomland hardwood forest to cypress-tupelo swamp. The area immediately adjacent to the effluent input is a shallow, treeless, open water area because trees were cleared for the construction of a power line right of way. Beginning in 1992, secondarily-treated municipal effluent from Thibodaux has been discharged to the site through 40 outlets along the northern edge of the study area. Prior to effluent discharge, the only significant freshwater inputs were precipitation and backwater flooding. The water flows south about 2 km where it exits the site between an oil access road and bottomland hardwood ridge. Water then enters a larger 1431 ha wetland before flowing into the Terrebone-Lafourche drainage canal (figure 2.2).

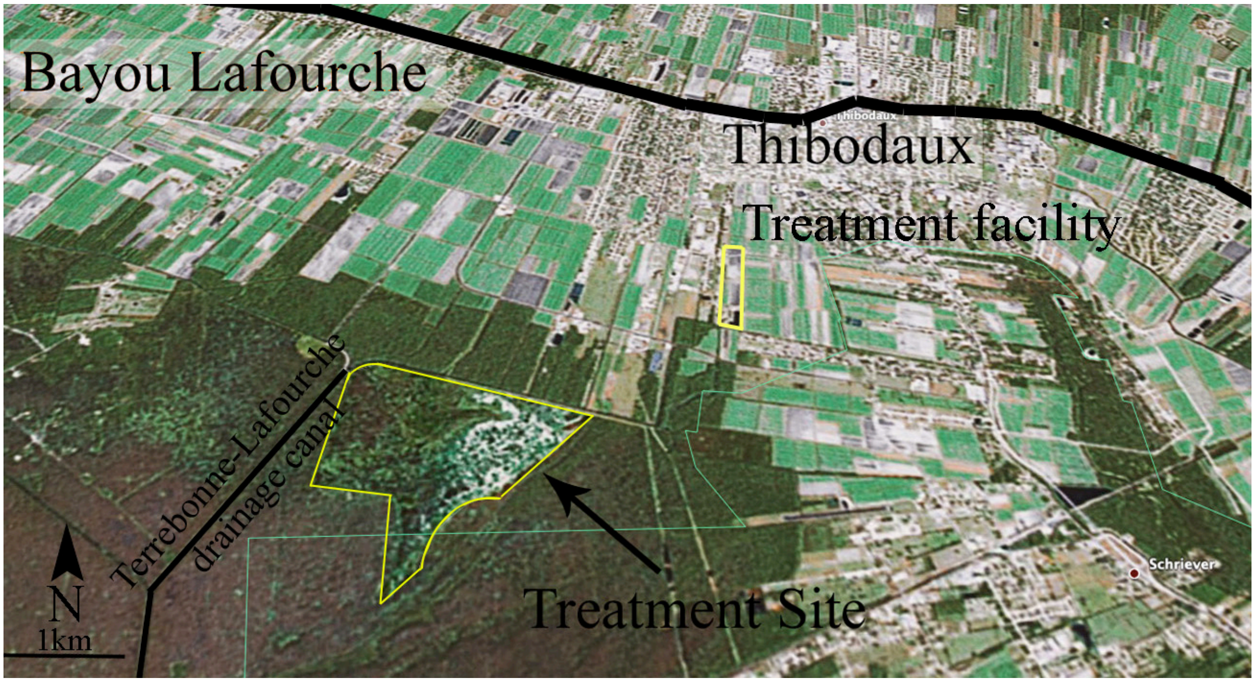

Figure 2.1 – Thibodaux, Louisiana and the relative location of the treatment facility.

Floating vascular plants now cover most of the open water area year round. Near the outfall, dominant species include *Typha*, *Panicum virgatum*, *Panicum hemitomon*, *Hydrocotyle umbellata*, and *Alternanthera philoxeroides*, Toward the southern end of the wetland, *Panicum spp.* become less-common while *Lemna*, thin-mat flotants of *eleocharis* and other sedges exploit canopy gaps in the otherwise baldcypress (*Taxodium distichum*) and water tupelo (*Nyssa aquatica*) dominated swamp. The bottomland-hardwood ridge (mean elevation = 1.16m above MSL) is approximately 300m wide and is vegetated with oaks (*Quercus nigra* L. and *Q. texana* Buckly), sweetgum (*Liquidambar styraciflua* L.), American elm (*Ulmus Americana* L.), palmetto [*Sabal minor* (Jacq.) Pers.], and boxelder (*Acer negundo* L.).

The climate is subtropical with a mean annual air temperature of 20.6^{o}C, ranging from 13.0^{o}C in January to 27.5^{o}C in July. Mean annual precipitation is 1670 mm yr^{-1}, and has ranged from 790 mm in 1962 to 2220 mm in 1940 (Conner and Day, 1989).

Numerous studies (published as agency reports, dissertations, conference proceedings, or in the refereed literature – see appendix, also summarized by Day et al. (2004) have been conducted at the Point au Chene Swamp. Four documents, prepared for the Louisiana Department of Environmental Quality, document pre-discharge baseline environmental conditions and four years of post effluent monitoring at the site (Conner and Day 1990, Day et al. 1993; Day et al. 1994; Day et al 1998). Zhang et al. (2000) and Rybczyk et al. (1996) described the effects of wastewater effluent on water quality, sediment nutrient concentrations.

2.2 Field Studies

To study floating marsh dynamics, a five plot transect was established (15m, 30m, 45m, 60m, and 75m from the point of effluent discharge), within which monthly sampling was carried out for physical and chemical parameters (dissolved oxygen, temperature, nitrate-nitrite, ammonia-ammnium, total kedjahl nitrogen (TKN), phosphate and total phosphorus (TP)), and above and belowground biomass.

Dissolved oxygen and water temperature *in situ* were measured below the floating mat at each site using a Yellow Springs Instrument. Water samples were collected below the floating mat by gently lowering 1000ml acid-washed polyethylene bottles through gaps in the floating marsh. The samples were stored on ice and taken to the laboratory for analysis. Inorganic nitrogen analyses were performed using standard methods outlined by the Environmental Protection Agency and the Louisiana Department of Environmental Quality, (Environmental Protection Agency 1979) and included the following: nitrate-nitrite, #353.2; and ammonium, #350.1. Samples to be analyzed were filtered using a 0.45µm millipore filter and concentrations were determined by Ion Chromatography (Dionex I.C. Model 2010i).

To estimate seasonal growth dynamics of the dominant plants, total above ground biomass was collected monthly at five replicate plots (0.1 m^2) at sites 15m, 45m, and 75m by cutting all vegetation at the sediment or water interface. Species composition, and dry weight of living and dead material were measured. Annual productivity was estimated using Smalley's (1958) method.

End of season total standing crop and was harvested in mid-October along with dead plant material, belowground roots, and consolidated peat. Above and belowground sections of floating mat were sampled at the 15m, 45m, and 75m stations in five replicate 0.25m^2 quadrants. Live plants, live roots, and dead organic material were dried and weighed separately so that the contribution of each to the mass of the floating mat could be estimated.

Two of the five plots at each station and 4 additional plots (100m, 200m, 400m, 800m) along a 2 km transect were sub-sampled seasonally to determine isotopic ratios of carbon, nitrogen, and sulfur. The samples were field composites sorted to species, rinsed, dried at 60 °C, pulverized, and analyzed for elemental and isotopic compositions with an automated analytical system combining an isotope ratio mass spectrometer (Finnigan Delta Plue, Thermo Electron Corporation, Waltham, Massachusetts, USA) and an elemental analyzer (Carlo Erba NA 1500, Thermo Electron Corporation) (Fry et al., 2002). Several samples were split in the laboratory and analyzed in duplicate. Laboratory split samples usually gave isotopic compositions that agreed within a 0.5‰ range (Appendix C). Combustion was performed in a single column to reduce dead space and maximize signals (Carmen and Fry 2002). The column was filled with reduced copper wire of 0.3 mm diameter, and temperature was maintained at 850°C to avoid melting of the filters. Results are reported in δ notation relative to international standards for Vienna Peedee belemnite (VPDB) for $\delta^{13}C$, N_2 in air for $\delta^{15}N$, and Vienna Canyon Diablo Troilite

(VCDT) for $\delta^{34}S$. Isotopic abundances are given a $\delta X=[(Rsample/Rstandard)-1]*1000$ where X is ^{15}N for nitrogen, ^{13}C for carbon, or ^{34}S for sulphur and R is $^{15}N/^{14}N$ for $\delta^{15}N$, $^{13}C/^{12}C$ for $\delta^{13}C$ or $^{34}S/^{32}S$ for $\delta^{34}S$ (Wissel et al, 2005). Isotopic values of *P. virgatum*, *H. umbellata*, and the bulk floating mat are reported relative to air N2 (0.0‰), Peedee Belemnite limestone (0.0‰) and (Sulfur Standard). Blank corrections based on analyses of pre-combusted GF/F filters without sample materials were made for all elemental and isotopic determinations, and NIST 1557b Bovine Liver was analyzed routinely with samples as a check standard (Fry et al. 1992). The peat material of the floating marsh was not acidified to remove carbonate because spot checks made by dropping 1 mol L^{-1} HCl onto wetted filters did not show bubbling that would indicate presence of carbonates.

2.3 Statistical Analysis

Error of individual samples are assumed to be within 5%. Confidence intervals (α=0.05) were developed around the mean annual nutrient concentrations. A one-way analysis of variance was run to examine differences in environmental characteristics, standing biomass, nutrient concentrations (NH_4, NO_3), and isotopic ratios of carbon and nitrogen. Alpha levels of 0.05 were considered significant.

Figure 2.2 – Aerial image of the treatment area showing the physical boundaries, locations of transects, and the outsite (Modified from the 2004 DOQQ).

3 RESULTS

3.1 Inorganic Nitrogen

Before the discharge of treated effluent, surface water inorganic nitrogen concentrations were similar in the treatment area and surrounding wetland (Day et al. 1989). Nitrogen concentrations were generally low and similar to values reported for surface waters in other southern bottomland hardwood and cypress swamps (Table 3.1). The annual mean concentrations of NH_4-N and NO_3-N + NO_2-N in the Pointe au Chene swamp during the 1988 - 1989 pre effluent period were 0.05 mg l^{-1}, 0.01 mg l^{-1}, and 1.34 mg l^{-1}respectively.

Table 3.1 – Mean seasonal inorganic nitrogen concentrations.

Date		3/31/05	4/20/05	5/24/05	6/17/05	7/29/05	8/26/05	10/3/05	10/21/05	12/2/05	Average + SD		Confidence (α = 0.05)	variance	Pre-discharge (1988-1989)	refrence area
Nitrate	Inlet	7.46	3.47	4.34	6.23	5.73	12.03	5.00	4.49	2.06	**5.65**	**2.9**	**1.9**	8.2	0.01	0.26
	15	2.13	2.86		3.65	5.13	6.59	1.41	0.37	1.65	**2.97**	**2.1**	**1.4**	4.3	0.01	0.26
	30		0.67		2.50	2.28	5.13			0.70	**2.26**	**1.8**	**1.2**	3.3	0.01	0.26
	45	0.93	0.83	0.83	0.75	2.68			0.32	0.28	**0.95**	**0.8**	**0.5**	0.7	0.01	0.26
	60		0.42		0.56	1.12	2.50	0.31	1.05	0.21	**0.88**	**0.8**	**0.5**	0.6	0.01	0.26
	75	0.22	0.33		0.22	0.96	1.19		1.23	0.62	**0.68**	**0.4**	**0.3**	0.2	0.01	0.26
	Out	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**	**0.0**	**0.0**	0.0	0.01	0.26
Ammonia	Inlet	3.60	3.73	3.70	3.63	3.68	3.81	3.67	3.86	3.92	**3.73**	**0.1**	**0.1**	0.0	0.05	0.04
	15	3.15	3.30	3.62	3.01	3.59		3.43	3.85	4.11	**3.51**	**0.4**	**0.2**	0.1	0.05	0.04
	30		2.63	3.39	3.55	3.74		3.96	3.60	3.72	**3.51**	**0.4**	**0.3**	0.2	0.05	0.04
	45	3.69	3.57	3.02	3.72	3.58		3.87	3.95	4.18	**3.70**	**0.3**	**0.2**	0.1	0.05	0.04
	60		3.46	3.80	3.65	3.66	3.71	3.20	4.03	4.00	**3.69**	**0.3**	**0.2**	0.1	0.05	0.04
	75	3.69	3.66	1.84	3.76	3.31	3.68	4.00	3.97	4.01	**3.55**	**0.7**	**0.4**	0.5	0.05	0.04
	Out		0.24	0.38	0.24	0.22	2.76	1.78	0.27	0.26	**0.77**	**1.0**	**0.6**	0.9	0.05	0.04

The effluent is highly nitrified with NO_3 as the major form of inorganic nitrogen. Inlet total inorganic concentrations were typically above 9 mg l^{-1} and were as high as 16 mg l^{-1} (Table 3.1). Except during December, nitrate was always the dominant inorganic form of N in the effluent, averaging 5.4 ± 2.9 mg l^{-1}, although the inlet concentration was highly variable between sampling efforts. Nitrate decreased significantly from the inlet to 100m and was always below the detection limit at the out site (figure 3.1). Ammonium concentrations were consistently between 3.0 and 4.0 mg l^{-1}over the entire study period and had an average value of 3.73 ± 0.1 mg l^{-1}. Ammonium showed no significant change in concentration over the first 75m, however outlet concentrations were significantly reduced ($p < 0.001$) relative to inlet concentrations averaging 0.77 ± 0.9 mg l^{-1}. The highest out-site concentrations of ammonium were 2.76 and 1.78 recorded August 27th and October 4th, respectively. These concentrations were lower (outside 95% confidence interval) than August/October transect concentrations, although significantly higher than the out-site at any other date.

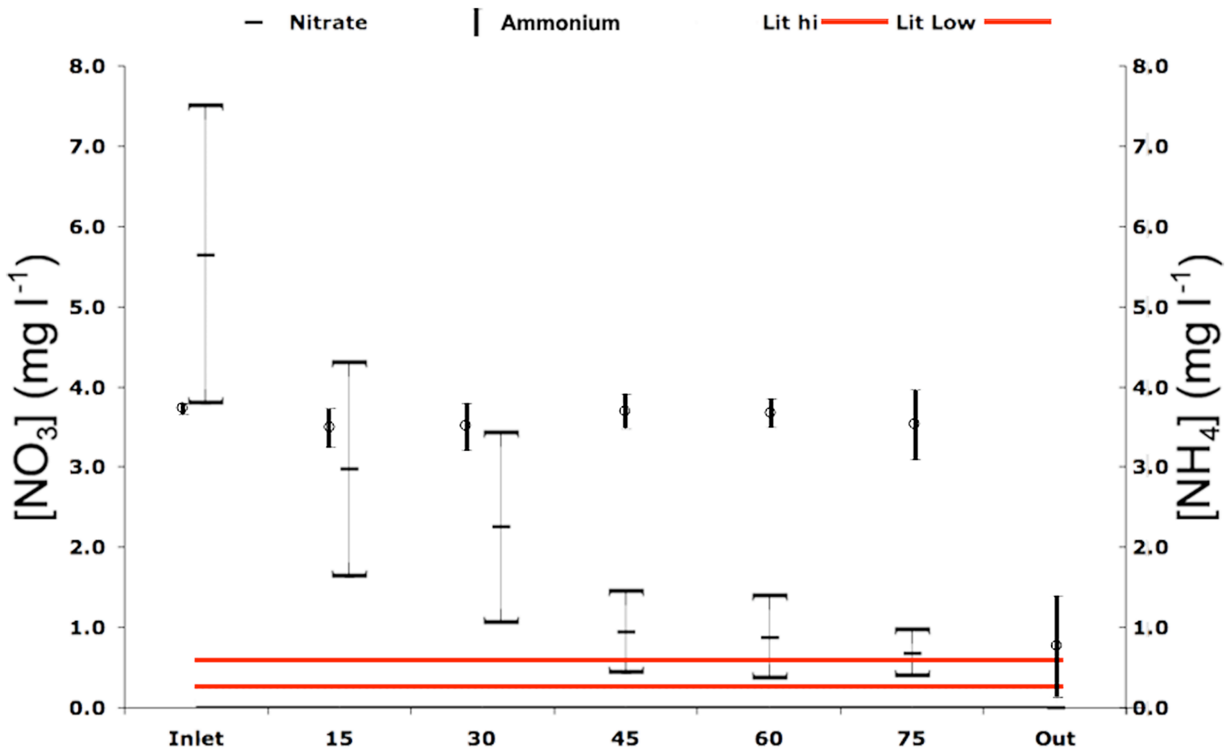

Figure 3.1 - Mean annual nitrate and ammonium concentrations (95% CI) along the transect and at the out site. The range of inorganic nitrogen for wetlands of similar geomorphology is given (Hopkins and Day 1979, Witzig and Day 1983, Kemp and Day 1984, Day and Kemp 1985)

3.2 Floating Marsh Productivity

Total floating marsh biomass was highest near the outfall and decreased along the 75m transect. Total Belowground (living and dead) biomass was 4079.0 ± 298.5 g m^{-2} at the 15m station, most of which was slowly decomposing materials with the upper portion live roots and fibrist *P. virgatum.* Total belowground mass was 1596.2 ± 373.7 g m^{-2} and 472.7 ± 125.8 g m^{-2} at the 45m and 75m stations. End of season live biomass (EOSL) was 669.9 ± 131.8 g m^{-2}, 372.5 ±

54.8 g m^{-2}, and 287.2 ± 57.3 g m^{-2} at the 15m, 45m, and 75m stations, respectively. *H. umbellata* biomass made up a greater portion of EOSL at stations 45m and 75m (table 3.2) while there was no difference between *P. virgatum* (357.0 ± 110.3 g m^{-2}) and *H. umbellata* (313.0 ± 21.5 g m^{-2}) EOSL at 15m.

Table 3.2 – NAPP, End-of-season live biomass (EOSL), and estimates of belowground biomass.

	15m		45m		75m	
NAPP	**3876.08**	**g m^{-2} y^{-1}**	**1049.58**	**g m^{-2} y^{-1}**	**832.50**	**g m^{-2} y^{-1}**
	Biomass (g m^{-2})	±	Biomass (g m^{-2})	±	Biomass (g m^{-2})	±
EOSL	**669.9**	**131.8**	**372.5**	**54.8**	**287.2**	**57.3**
H. umbelata	313.0	21.5	291.5	23.6	254.1	18.0
P. virgatum	357.0	110.3	81.0	31.3	33.1	39.3
Total Belowground	**4079.0**	**298.5**	**1596.2**	**373.7**	**472.7**	**125.8**
H. umbelata	561.1	31.0	424.8	44.7	359.2	41.0
P. virgatum	370.4	36.4	143.0	13.1	113.4	84.8
Dead	3147.4	231.1	1028.4	315.9	0.0	0.0

Net annual aerial primary productivity (NAPP) was highest at 15m (3876 g m^{-2}y^{-1}) where the productivity of *P. virgatum* was highest (2736 g m^{-2}y^{-1}), and decreased with distance. *H. umbellata* productivity was lowest at 15m relative to the 45m and 75m stations (figure 3.5b). NAPP decreased with distance from the effluent discharge (figure 3.4) and was primarily supported by *H. umbellata* at the 45m and 75m stations. The peak standing crop of *P. virgatum* occurred in June (1471.9 ± 847.1) then declined to less than 400 g m^{-2} at the end of season harvest. *H. umbellata* biomass was generally robust in the cooler months from October to April, when *Panicum* growth was constrained by temperature. Winter standing crops at all sites were typically above 300 g m^{-2}. The lowest values, typically less than 200 g m^{-2}, were recorded during the summer and where *P. virgatum* was present (figure 3.5a). *Hydrocotyle* biomass was low from June to August at all sites, regardless of the presence of competing species (Figure 3.5a-b).

Over the 12-month study period, *P. virgatum* was collected during every sampling at 15m (n = 12), between June and December at 45m (n = 6), and from August to October at 75m (n = 3) while *H. umbellata* was always encountered. At 15m, *P. virgatum* regeneration was observed from seed and rhizome while the 45m and 75m stations showed almost exclusively seed. Seedlings at 75m were observed to be supported by the roots of *H. umbellata* where peat had not accumulated. This suggests that while *P. virgatum* can germinate in all of the floating marsh area but that the growth and persistence of mature plants, and therefore expansion of the floating marsh, are constrained by environmental factors.

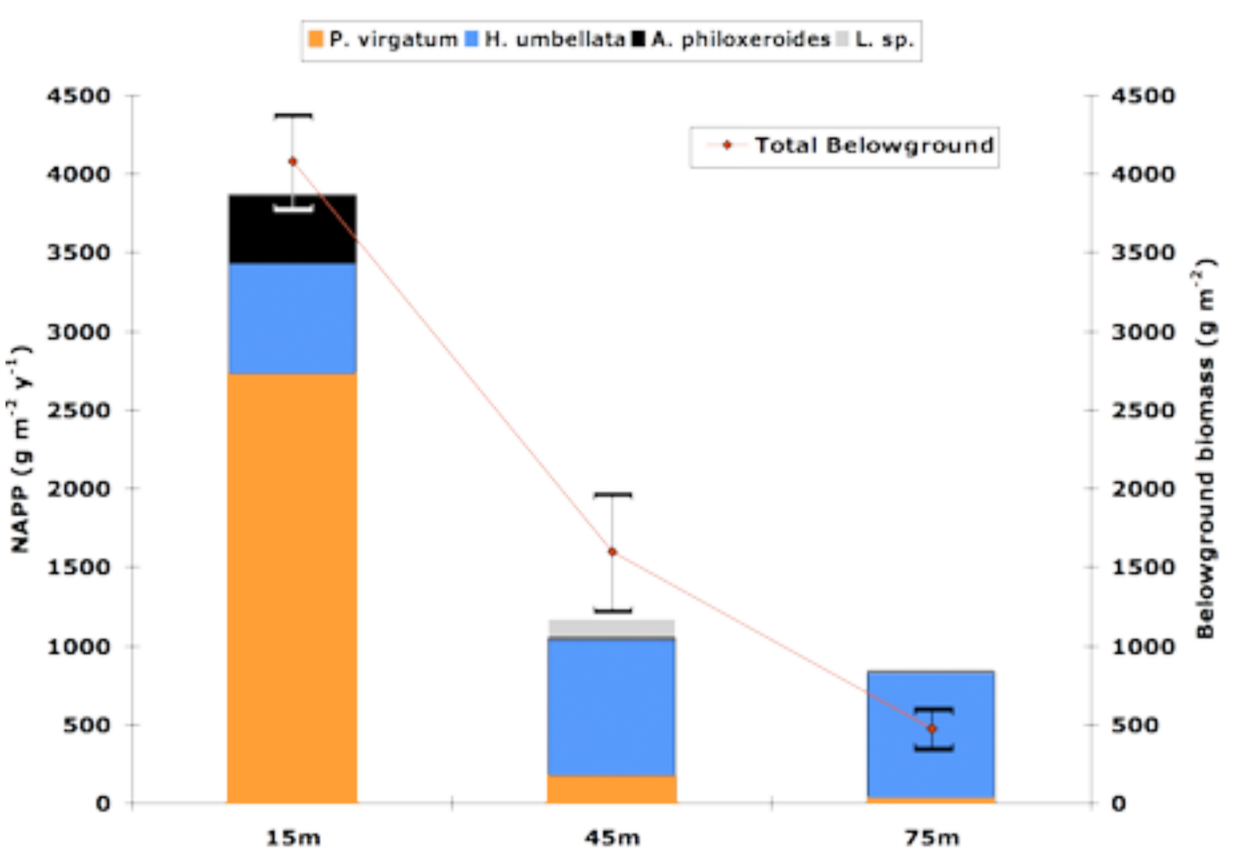

Figure 3.2 – NAPP and Total Belowground Biomass for transect stations showing the relative contributions of dominant species.

During the early spring seedlings of *P. virgatum* at 15m were limited to areas on the floating mat where *H. umbellata* was absent. As it matured, *P. virgatum* was easily able to out-shade and displace *H. umbellata*. The highest growth of *P. virgatum* occurred between June and August at station 15m and was coincident with the lowest biomass of *H. umbellata* (figures 3.4

and 3.5). Emergence of *P. virgatum* seedlings at stations 45 and 75m was delayed until mid-summer when cover of *H. umbellata* seemed to falter (figure 3.4) allowing for greater light penetration to the surface of the floating mat. Additionally, the marsh directly adjacent to the effluent discharge was not truly floating between June and August, rather it was supported by fluid ooze. During this period, channels in the marsh were also observed with flow velocities up to 0.5m/s that may have altered the nutrient gradient and caused some marsh erosion. Seedlings of *P. virgatum* were observed growing atop the floating mat in June at 45m and associated with *H. umbellata* roots in August at 75m. However these stations did not achieve biomass comparable to 15m before transitioning to *H. umbe*llata monocultures.

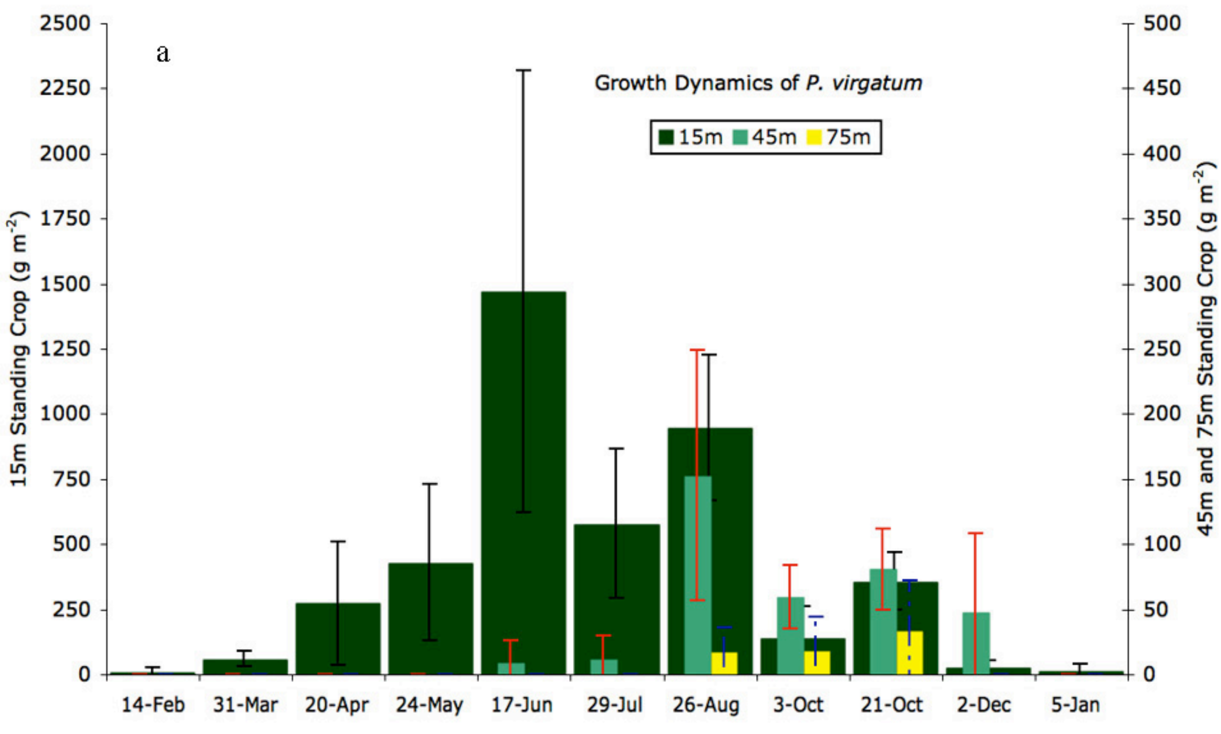

Figure 3.3 - Seasonal growth dynamics of *P. virgatum*.

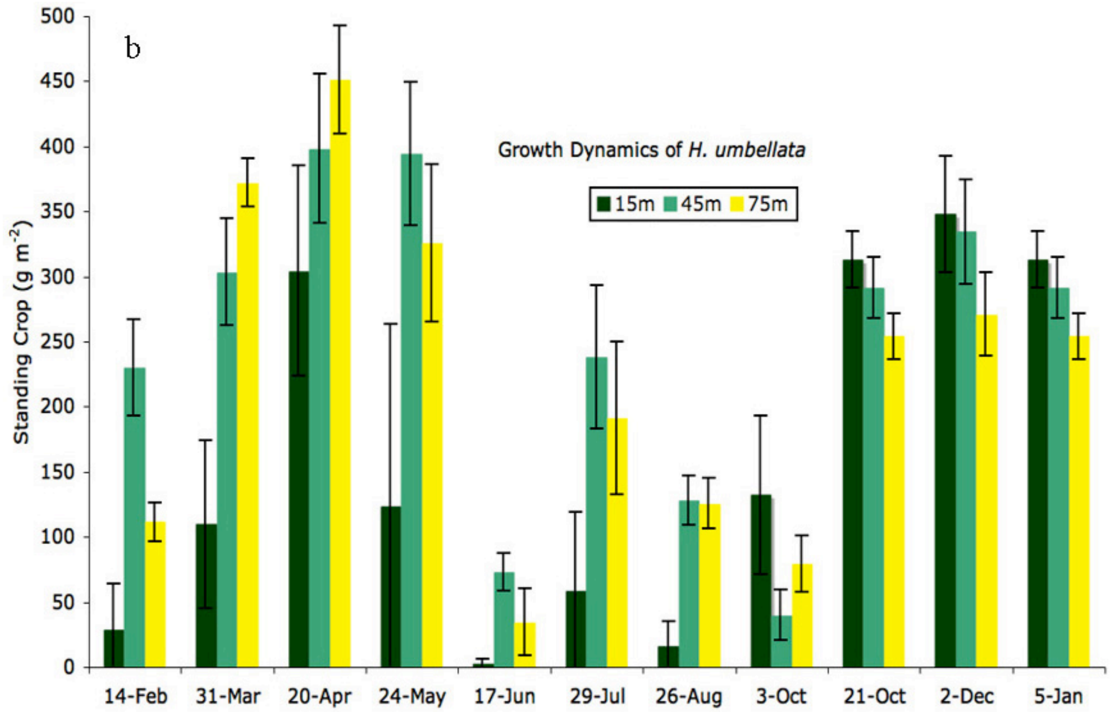

Figure 3.4 - Seasonal growth dynamics of *H. umbellata*.

Net annual primary productivity was 3.7 times greater at 15m than 45m, mostly due to *P. virgatum* growth between June and August (figure 3.3). At 45m and 75m *P. virgatum* biomass declines (P=0.02) while there was no significant difference in *H. umbellata* biomass along the transect (P=0.12).

3.3 Isotopic Values

Isotopic analysis of plant tissues revealed mean $\delta^{15}N$ values of *H. umbellata* were 9.7 $^{o}/_{oo}$ to station 75m and 21.0 $^{o}/_{oo}$ to a distance of 400m . The $\delta^{15}N$ values of *P. virgatum* showed a similar enrichment with distance, however with peak values somewhat lower than *H. umbellata* (Appendix C). Isotopic values were used to determine the dominant source material of the floating marsh. Figure 1.8 shows differential $\delta^{13}C$ values in *H. umbellata* and *P. virgatum* while the peat $\delta^{13}C$ is similar to $\delta^{13}C$ of the grass *P. virgatum*.

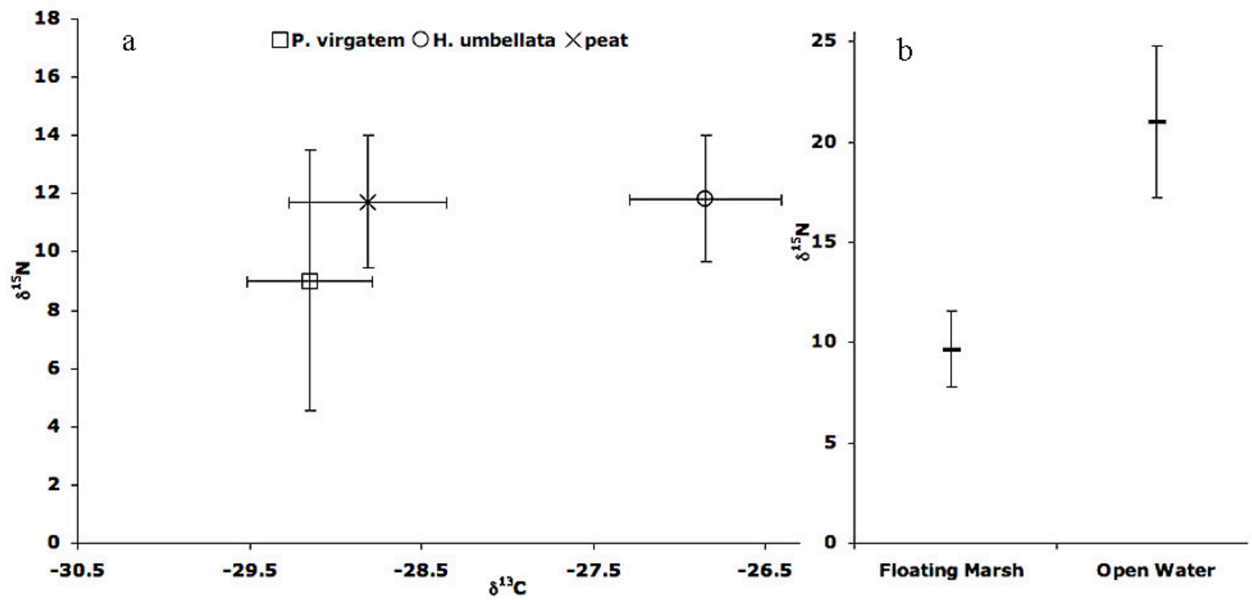

Figure 3.5a - Mean Carbon and Nitrogen isotopic values of the floating marsh community. b. mean $\delta^{15}N$ values of *H. umbellata* on the floating marsh transect (0-75m) and in open water and (100-200m). All values reported with 95% confidence intervals.

4 DISCUSSION

The floating marsh initially developed as a floating emergent aquatic wetland dominated by *H. umbellata* eight years after the initiation of the treated effluent discharge. Baseline nutrient concentrations (prior to nutrient additions) indicated the system was similar to other impounded oligotrophic wetlands in the Mississippi delta plain. Nitrogen was supplied by precipitation on the order of 0.5 g m^{-2} y^{-1} (Nixon 1980). Between 2000 and 2001, *P. virgatum* became established along the edge of the spoil bank next to the discharge and over four years developed into a productive marsh with floating marsh characteristics and extended about 75 m into shallow open water area. The *P. virgatum* marsh developed in a floating form in an area that prior to effluent addition was relatively clear, shallow water above a clay pan (Breaux and Day 1994). Mechanistically this suggests floating marsh initiation from shoreline attachment, as theorized by Russel (1942). Other documented mechanisms of floating marsh formation require organic debris accumulating on the bottom of shallow water bodies. As it decays it becomes buoyant and is subsequently colonized by grasses and sedges (Cypert 1972, Rich 1984). Currently the most commonly accepted theory for creation of Louisiana floating marshes is that over time a buoyant peat mass with its living vegetation breaks free from its subsiding substrate and floats freely (O'Neil 1949, Sasser et al, 2006).

A number of factors contributed to the development of the floating marsh in the study area. In particular, the low energy backswamp setting has no visible flow, is continuously fresh, and the constant effluent supply over time altered the baseline chemistry by establishing a strong nutrient gradient. Low oxygen levels under the mat lead to low rates of organic matter decomposition. Nutrient stimulated productivity coupled with suppressed decomposition allow for peat accumulation, critical to the development of a floating marsh. Suitable conditions for *P.*

virgatum floating marsh development are thus related to the effluent discharge coupled to biogeochemical conditions in the receiving area.

4.1 Nutrient Chemistry

Within the 75m transect, few changes in nutrient concentrations were observed. Ammonia remained relatively stable while there was a dramatic decrease of nitrate (figure 3.1). Denitrification, which is an important pathway leading to nitrate reomval, has been documented at Thibodaux and in similar assimilation wetlands where nitrate is the dominant form of inorganic nitrogen in the effluent (Day et al, 2004, Crozier et al. 1996, Boustany et al. 1997). Furthermore, the denitrification potential of constructed wetlands has been shown to increase over time (Hernandez and Mitsch, 2006). Oxygen can limit the rate of decomposition in wetland systems leading to a buildup of organic matter (Mitsch and Gosselink 2003, Rybczyk et al 2002) and low bulk density soil, thus contributing to floating marsh stability (Sasser 1994).

Over the entire wetland transect, significant reductions occurred in both NO3 and NH4 and nitrate was often below the detection limit at the outflow. Ammonia concentrations decreased to the range reported for natural forested wetland systems in Louisiana and elsewhere (Appendix B,). Similar nutrient reductions by multiple loss pathways have been observed in assimilation wetlands throughout the delta plain and other areas (Day et al. 2004, Kaldec and Knight 1996; Richardson and Davis 1987). Permanent loss pathways such as denitrification and burial are important to the sequestration of nutrients (Kaldec and Alvord 1989; DeLaune and Patrick 1990, Baustany et al, 1997).

Carbon stable isotope ratios have been used in a number of studies to determine source contributions to a given carbon pool (Fry 2006). The $\delta^{13}C$ analysis provided a clear distinction between plants living on the floating marsh and those directly contributing to belowground mass showing that P. virgatum formed almost all of the peat. Carbon isotope values consistently differed between *H. umbellata* and *P. virgatum*, thus allowing for resolution between the carbon sources and definite identification of *P. virgatum* as the species responsible for the bulk of the floating marsh mat material (figure 3.5a).

The elevated $\delta^{15}N$ values observed were typical of nutrient enriched conditions in aquatic habitats and offer insight to the active transformation pathways. Numerous studies have documented $\delta^{15}N$ enrichment across nitrogen concentrations gradients (Altabet 2001, Cole et al, 2004; Verekamp and Altabet 2006), coincident with point and non-point nitrogen sources, and many have used tracer experiments to understand the chemical transformations of DIN in wetland environments. Figure 3.5b shows $\delta^{15}N$ differences across the floating marsh transect for *H. umbellata.* Because the $\delta^{15}N$ value represents the total nitrogen in the plant tissue no distinction can be directly made between DIN species. However the trend of increasing tissue $\delta^{15}N$ with distance is consistent with rapid, selective NO_3 uptake and denitrification favoring $\delta^{15}N$ enrichment in the remaining fraction. Another way this enrichment could arise requires elevated effluent-source ammonia originating in the treatment facility. There was no net concentration change in NH_3/ NH_4 in 75m. This could be due to the low oxygen of the floating marsh mat environment preventing oxidation to ammonium (Mitsch and Gosselink 2000). Under these conditions the marsh plants may be showing preference for nitrate over ^{15}N-enriched ammonia. Beyond 75m the factors promoting anoxia are less and the concentration of nitrate is reduced dramatically. Thus $\delta^{15}N$-enriched ammonium becomes the most readily available nitrogen form for plant uptake. In either case the data suggests nitrate transformations occur early and rapidly below the floating marsh following discharge. This is consistent with measurements of high denitrification rates in assimilation wetlands (Day et al, 2004; DeLaune et al, 1986; Crozier et al. 1996; Boustany et al. 1997; Hernandez and Mitsch 2006) and high overall rates of nutrient assimilation systemwide.

4.2 Vegetation Growth Dynamics

The effluent discharge affected the dynamics of floating marsh development. High inorganic nutrient input established a strong environmental gradient that replaced pre-discharge homogenous, stagnant oligotrophic waters. The response to the nutrient gradient was robust growth and expansion of emergent aquatic vegetation and the initiation of a floating marsh. The 15 years of effluent discharge increased the availability of DIN, phosphate, and labile organics (Zhang et al, 2000) and likely influenced the patterns of plant succession observed in this study. *P. virgatum*, not known to readily grow and expand into open water, greatly increased the productivity of the shallow open water zone with the development of a floating marsh. However, the thickness of this marsh increases toward the upland end where it is truly floating except during peak growing season when it is supported by a thick organic muck. The ability of *P. virgatum* to exist as a floating form requires biomass production in excess of plant decomposition. In fertilization studies, *P. virgatum* has been shown to have a high nitrogen requirement to achieve high biomass yields (George et al, 1995). The NAPP of *p. virgatum* (2736 g $m^{-2}y^{-1}$) was higer than typical values for *p. hemitomon* (970 g $m^{-2}y^{-1}$) floating marsh (Hatton et al. 1983, Pezeshki and DeLaune 1991, Sasser 1994) and was generally higher than fertilized growth of *P. virgatum* in bioenergy studies (Vogel et al, 2002, McLauglin and Kszos 2005). However, several studies reported by McLauglin and Kszos (2005) using the best-bred varieties showed equivalent annual productivity to the values reported in this study. Along the 75m transect the wetland transitions from *P. virgatum* dominated marsh with flotant characteristics (i.e. free floating, rooted in a substrate with soil-like properties) to an emergent aquatic community dominated by *H. umbellata*, but *P. virgatum* was encountered at all sites. Beyond 75m *Panicum* was extremely uncommon.

P. virgatum exhibited a seasonality affected by autogenic (intraspecies competition, grazing) and allogenic (nutrient and freshwater inputs) forces. When growing in the absence of other species, *Panicum* seedlings emerged early in February. However, the cool-weather adapted *H. umbllata* produced greater biomass during the winter and spring months (figure 3.4, Agami and Reddy, 1991; Reddy and DeBusk 1984), especially at the 45 and 75m stations, and effectively shaded the sediment interface until growth slowed in June. Hydrocotyle growth contributed to late development of *P. virgatum* and thus exhibited an autogenic control on seasonal biomass yield, an important component of floating marsh development.

Marsh development may be confounded where *Hydrocotyle* growth prevents the widespread germination of *Panicum* seedlings through the spring and also the growth response to nutria, an introduced species known to trample and consume *P. virgatum*. In enclosures, *P. virgatum* persisted year-round near the effluent discharge. Outside the enclosures the marsh converted to nearly 100% cover by *Hydrocotyle* at the onset of winter. Decreases in biomass during the growing season at 15m may be due to herbivore activity. The exotic species nutria *Myocaster coypus*, has been implicated in many areas of coastal Louisiana with decreased aboveground plant productivity and increased open area (Schaffer et al, 1992; Sasser 2007, Holm and Sasser 2001). With regard to *P. virgatum*, Taylor and Grace (1995) found biomass to be significantly reduced in the presence of *Myocaster coypus* in the freshwater areas of the Pearl River basin. The decreased biomass of *P. virgatum* at the end of season relative to its peak biomass was in part caused by grazing and a seasonal characteristic of both *P. virgatum* and *P. hemitomon*. Plant biomass was likely incorporated into the marsh.

We conclude that the addition of freshwater and nutrients can be beneficial to the establishment of this type of flotant, and in turn the productivity of the marsh increases the capacity of the wetland to take up nutrients. The maintenance and expansion of this marsh may lead to the organic filling of the zone of open water and eventually the filling of the shallow water area and the conversion to a rooted marsh. Presently, more sophisticated enclosures containing *P. hemitomon* have been deployed to determine possible successional pathways for flotant development in the absence of grazers (G. Holm, personal communication). *P. hemitomon*, a known flotant building grass, was selected for its enhanced anaerobic tolerance and long growing season (USDA) relative to *P. virgatum*. The nutrient response of *P. hemitomon* has not been examined in this type of system and therefore there is a novel opportunity to study the zonation and community interactions in response to the artificial environmental gradients.

In the future, the addition of freshwater will buffer any threat from any salt intrusion and likely continue to support a productive floating or attached marsh within the high-nutrient low-energy system.

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APPENDIX A – ABOVE GROUND BIOMASS DATA

Live *Panicum virgatum*

	Date = / Sample	14-Feb	31-Mar	20-Apr	24-May	17-Jun	29-Jul	26-Aug	3-Oct	21-Oct	2-Dec	5-Jan
Near	1	1.20	14.20	79.30	250.70	1422.00	269.40	784.80	210.00	209.50	0.00	7.90
	2	2.60	104.20	631.70	924.50	48.60	894.00	1071.30	344.50	512.40	20.90	0.00
	3	0.20	42.50	473.00	9.60	1157.00	256.00	1412.60	17.40	288.00	28.30	0.00
	4	41.90	65.10	183.60	404.50	2437.00	935.10	560.90	24.20	314.00	0.00	63.20
	5	8.60	74.00	0.00	560.40	2295.00	537.50	917.60	100.30	461.00	80.50	0.00
	Average	10.90	60.00	273.52	429.94	1471.92	578.40	949.44	139.28	356.98	25.94	14.22
	error	7.89	15.13	120.15	153.47	432.22	146.28	142.91	61.94	56.27	14.75	12.34
	Smalley	10.90	70.90	344.42	774.36	2246.28	2246.28	3195.72	3195.72	3552.70	3552.70	3552.70
Intermediate	1	0.00	0.00	0.00	0.00	0.00	0.00	278.50	34.20	59.20	43.10	0.00
	2	0.00	0.00	0.00	0.00	0.30	46.20	253.30	92.50	64.80	20.20	0.00
	3	0.00	0.00	0.00	0.00	44.30	0.00	99.90	38.20	135.20		0.00
	4	0.20	0.00	0.00	0.00	0.50	0.00	112.70	45.90	98.30	167.50	0.00
	5	0.00	0.00	0.00	0.00	1.20	14.00	19.90	86.40	47.60	9.50	0.00
	Average	0.04	0.00	0.00	0.00	9.26	12.04	152.86	59.44	81.02	48.06	0.00
	error	0.04	0.00	0.00	0.00	8.76	8.96	48.97	12.43	15.95	32.64	0.00
	Smalley	0.04	0.04	0.04	0.04	9.30	21.34	174.20	174.20	255.22	255.22	255.22
Far	1	0.00	0.00	0.00	0.00	0.00	0.00	52.80	22.30	2.50	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	23.60	2.50	111.40	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	8.80	0.00	15.60	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	67.50	7.50	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00	0.00	1.30	0.00	28.50	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	17.30	18.46	33.10	0.00	0.00
	error	0.00	0.00	0.00	0.00	0.00	0.00	9.82	12.95	20.06	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	0.00	0.00	17.30	35.76	68.86	68.86	68.86

Dead *Panicum virgatum*

	Date = / Sample	14-Feb	31-Mar	20-Apr	24-May	17-Jun	29-Jul	26-Aug	3-Oct	21-Oct	2-Dec	5-Jan
Mid	1	87.55	0.00	0.00	0.00	0.00	0.00	0.00	106.90	0.00	240.10	0.00
	2	51.67	0.00	0.00	0.00	0.00	0.00	0.00	265.60	0.00	0.00	0.00
	3	45.16	0.00	0.00	0.00	0.00	0.00	0.00	494.50	111.10	0.00	0.00
	4	96.59	0.00	0.00	0.00	0.00	0.00	0.00	140.70	0.00	0.00	0.00
	5	45.35	0.00	0.00	0.00	0.00	0.00	0.00	167.30	0.00	0.00	0.00
	Average	65.26	0.00	0.00	0.00	0.00	0.00	0.00	235.00	22.22	48.02	0.00
	error	11.10	0.00	0.00	0.00	0.00	0.00	0.00	70.06	22.22	48.02	0.00
	Smalley	65.26	65.26	65.26	65.26	65.26	65.26	65.26	300.26	300.26	348.28	348.28
Intermediate	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16.60	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	73.70	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19.40	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.94	0.00	0.00	0.00
	error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.56	0.00	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21.94	21.94	21.94	21.94
Far	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

LIVE *Hydrocotyle umbellata*	Date = / Sample	14-Feb	31-Mar	20-Apr	24-May	17-Jun	29-Jul	26-Aug	3-Oct	21-Oct	2-Dec	5-Jan
Near	1	19.70	160.60	405.30	114.00	0.00	129.10	0.00	61.00	33.60	350.30	289.70
	2	15.80	56.60	263.10	14.80	11.30	0.00	1.60	109.30	0.00	418.00	289.40
	3	10.30	207.10	211.20	397.40	0.00	0.00	39.50	88.40	22.10	343.90	347.70
	4	0.00	94.60	240.70	6.80	0.00	30.10	39.50	169.70	17.00	354.90	315.50
	5	99.00	29.60	402.00	83.60	0.00	135.60	0.00	234.30	25.00	274.00	322.50
	Average	28.96	109.70	304.46	123.32	2.26	58.96	16.12	132.54	19.54	348.22	312.96
	error	17.82	32.82	41.33	71.46	2.26	30.48	9.55	31.10	5.58	22.85	10.96
	Smalley	28.96	138.66	443.12	443.12	443.12	502.08	502.08	634.62	634.62	982.84	982.84
Intermediate	1	236.40	330.00	443.80	494.90	71.80	274.00	103.60	73.20	0.00	292.30	275.10
	2	299.00	235.30	361.00	352.30	69.10	145.50	138.30	26.40	119.80	285.00	295.40
	3	218.00	334.50	486.40	379.90	48.00	287.80	124.50	32.00	0.00	353.10	336.90
	4	213.00	343.80	374.30	410.70	87.30	283.30	116.00	17.90	72.00	395.60	277.40
	5	186.50	273.50	325.40	335.70	87.80	200.80	158.70	50.20	96.00	346.30	272.80
	Average	230.58	303.42	398.18	394.70	72.80	238.28	128.22	39.94	57.56	334.46	291.52
	error	18.88	21.02	29.25	28.10	7.30	28.08	9.49	9.86	24.68	20.55	12.03
	Smalley	230.58	534.00	932.18	932.18	932.18	1170.46	1170.46	1170.46	1228.02	1562.48	1562.48
Far	1	116.80	362.00	440.20	395.30	47.60	202.60	153.40	112.20	106.30	268.90	258.50
	2	105.40	366.10	469.70	243.10	77.30	191.60	128.40	65.00	28.40	253.60	266.70
	3	130.40	347.80	387.10	400.40	30.50	126.80	140.00	99.80	134.90	237.10	238.20
	4	85.70	384.50	443.30	302.30	2.50	295.70	107.40	59.40	50.60	263.60	228.40
	5	120.20	401.00	516.00	288.70	14.60	138.60	99.50	61.40	94.00	332.50	278.60
	Average	111.70	372.28	451.26	325.96	34.50	191.06	125.74	79.56	82.84	271.14	254.08
	error	7.63	9.27	21.02	30.95	13.11	29.97	10.00	11.01	19.22	16.27	9.20
	Smalley	111.70	483.98	935.24	935.24	935.24	1126.30	1126.30	1126.30	1209.14	1480.28	1480.28

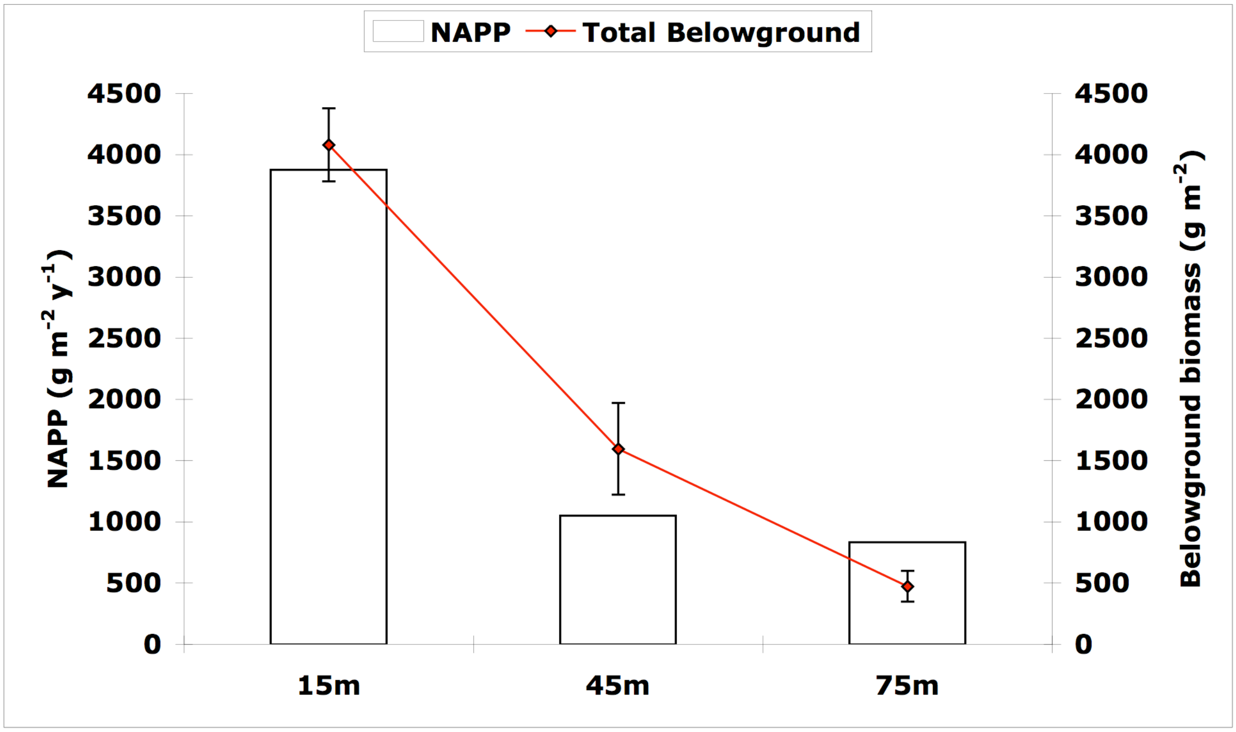
Dead *Hydrocotyle umbellata*	Date = / Sample	14-Feb	31-Mar	20-Apr	24-May	17-Jun	29-Jul	26-Aug	3-Oct	21-Oct	2-Dec	5-Jan
Mid	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	24.80	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	10.60	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	2.12	4.96	0.00	0.00	0.00	0.00	0.00
	error	0.00	0.00	0.00	0.00	2.12	4.96	0.00	0.00	0.00	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	2.12	7.08	7.08	7.08	7.08	7.08	7.08
Intermediate	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Far	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

LIVE *Alternanthera philoxeroides*

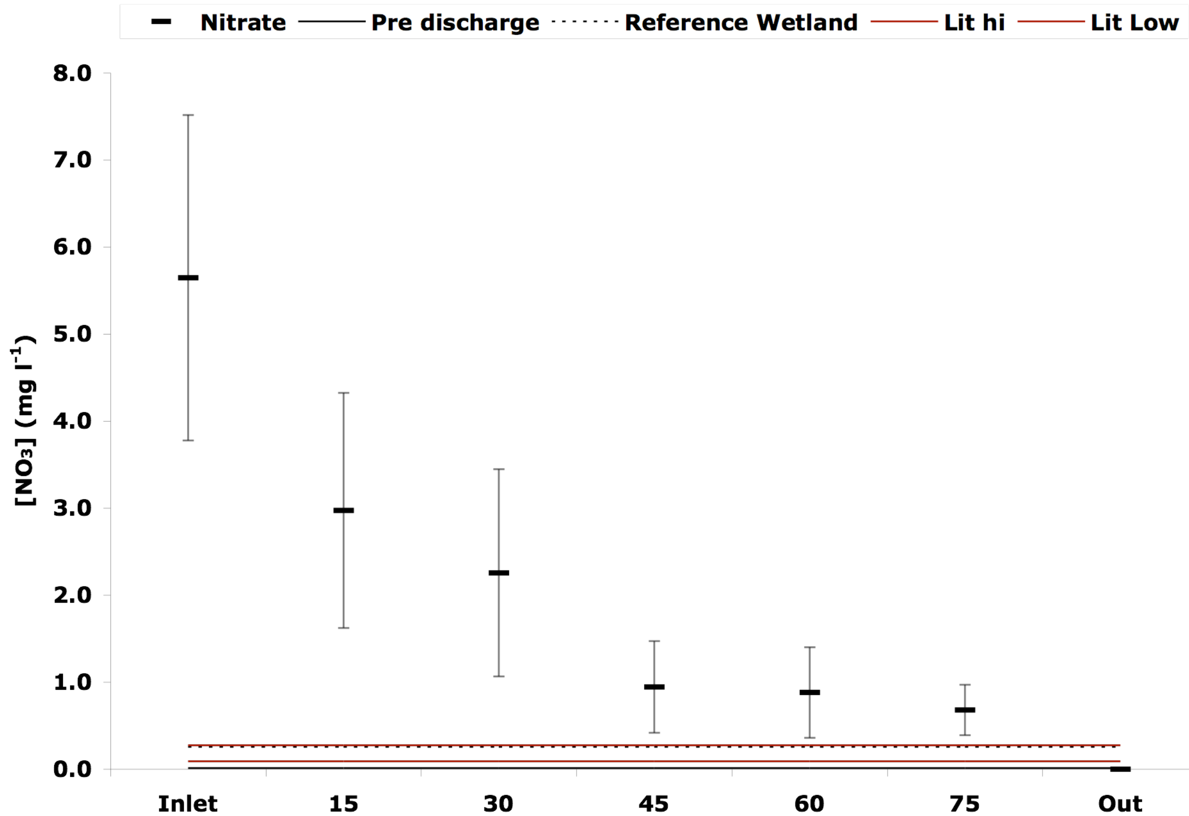
	Date = / Sample	14-Feb	31-Mar	20-Apr	24-May	17-Jun	29-Jul	26-Aug	3-Oct	21-Oct	2-Dec	5-Jan
Near	1	0.00	35.50	67.00	701.80	0.00	4.00	12.30	2.60	0.00	14.80	0.00
	2	7.90	0.00	63.90	195.70	22.00	0.00	8.00	0.00	0.00	0.00	0.00
	3	0.00	24.80	12.00	116.80	0.00	0.00	7.60	0.00	0.00	0.00	0.00
	4	21.70	90.50	0.00	102.70	0.00	0.00	40.20	47.70	0.00	0.00	0.00
	5	0.00	75.60	88.00	237.30	0.00	0.00	0.00	42.80	0.00	0.00	0.00
	Average	5.92	45.28	32.78	270.86	4.40	0.80	13.62	18.62	0.00	2.96	0.00
	error	4.23	16.63	17.03	110.57	4.40	0.80	6.93	10.91	0.00	2.96	0.00
	Smalley	5.92	51.20	51.20	322.06	322.06	322.06	335.68	354.30	354.30	357.26	357.26
Intermediate	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13.20	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	11.00	0.00	14.70	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.30	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.40	0.00	0.00	21.20	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00	0.00	29.70	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.08	0.00	8.14	12.74	2.94	0.00	0.00
	error	0.00	0.00	0.00	0.00	0.08	0.00	5.80	5.79	2.94	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	0.08	0.08	8.22	20.96	20.96	20.96	20.96
Far	1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

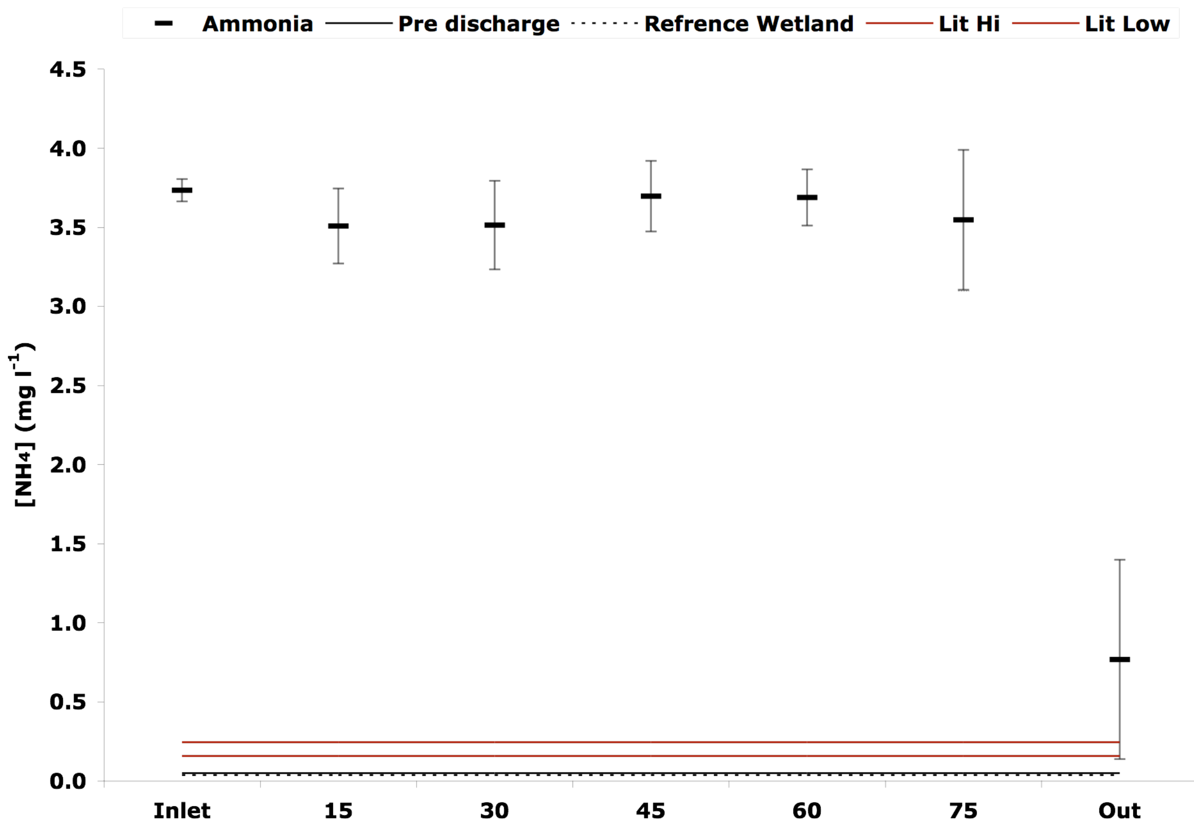
Dead *Alternanthera philoxeroides*

	Date = / Sample	14-Feb	31-Mar	20-Apr	24-May	17-Jun	29-Jul	26-Aug	3-Oct	21-Oct	2-Dec	5-Jan
Near	1	0	0	0	0	14.2	0	0	0	0	0	0
	2	0	0	0	0	445.3	28.2	0	0	0	0	0
	3	0	0	0	0	83.9	0	0	0	0	0	0
	4	0	0	0	0	35.8	0	0	0	0	0	0
	5	0	0	0	0	109.7	0	0	0	0	0	0
	Average	0.00	0.00	0.00	0.00	137.78	5.64	0.00	0.00	0.00	0.00	0.00
	error	0.00	0.00	0.00	0.00	78.72	5.64	0.00	0.00	0.00	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	137.78	137.78	137.78	137.78	137.78	137.78	137.78
Intermediate	1	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Far	1	0	0	0	0	0	0	0	0	0	0	0
	2	0	0	0	0	0	0	0	0	0	0	0
	3	0	0	0	0	0	0	0	0	0	0	0
	4	0	0	0	0	0	0	0	0	0	0	0
	5	0	0	0	0	0	0	0	0	0	0	0
	Average	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	error	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Smalley	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00


NAPP
Total Belowground
NAPP (g m-2 y-1)
Belowground biomass (g m-2)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
15m
45m
75m

APPENDIX B – WATER COLUMN NUTRIENT DYNAMICS




Ammonia
Pre discharge
Refrence Wetland
Lit Hi
Lit Low
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
[NH4] (mg l-1)
Inlet
15
30
45
60
75
Out

APPENDIX C - PLANT ISOTOPIC BIOGEOCHEMISTRY

Species	distance	Sample Wt.[mg]	$\delta^{15}N_{AIR}$	$\delta^{13}C_{VPDB}$	$\delta^{34}S_{VCDT}$	µgN	µgC	µgS	%N	%C	%S	C/N	1000 N/C	1000 S/C	1000 S/N
F05															
P. virgatum	0	11.38	3.47	-29.12	-2.87	256.41	4734.38	37.04	2.25	41.59	0.33	21.54	46.42	2.76	
P. virgatum	15	11.35	9.03	-28.80	-5.37	143.64	4676.85	48.53	1.27	41.19	0.43	37.98	26.33	3.66	
P. virgatum	30	10.10	10.00	-29.57	-4.63	136.01	4285.93	42.05	1.35	42.42	0.42	36.76	27.20	3.46	
P. virgatum	45	10.11	4.42	-28.73	-4.06	149.16	4096.02	27.44	1.48	40.53	0.27	32.04	31.21	2.36	
P. virgatum	60	11.64	8.02	-28.86	-4.69	165.67	4872.93	30.87	1.42	41.87	0.27	34.32	29.14	2.24	
P. virgatum	75	11.85	19.14	-29.83	-2.17	153.64	5061.00	36.01	1.30	42.69	0.30	38.43	26.02	2.51	
H. umbellata	0	11.06	9.82	-26.77	-7.16	243.76	3653.23	16.36	2.20	33.02	0.15	17.48	57.19	1.58	
H. umbellata	15	10.51	7.75	-26.04	-1.67	204.35	3870.51	13.10	1.94	36.82	0.12	22.10	45.25	1.20	
H. umbellata	15	10.21	7.86	-25.94	-1.92	194.84	3738.01	12.27	1.91	36.60	0.12	22.38	44.68	1.16	
H. umbellata	30	10.50	11.24	-27.52	-5.41	220.56	4046.72	14.98	2.10	38.55	0.14	21.40	46.72	1.31	
H. umbellata	45	10.78	14.33	-27.24	-2.29	276.02	4050.54	18.28	2.56	37.59	0.17	17.12	58.41	1.59	
H. umbellata	60	11.59	13.19	-27.13	-2.71	247.08	4124.65	15.42	2.13	35.58	0.13	19.48	51.35	1.32	
H. umbellata	75	10.02	14.69	-26.41	-1.82	241.99	3495.08	16.69	2.42	34.90	0.17	16.85	59.35	1.69	
H. umbellata - R	75	10.47	14.75	-26.28	-1.44	255.55	3709.69	15.87	2.44	35.44	0.15	16.94	59.05	1.51	
Marsh Mat*	0	11.81	6.03	-27.68	-14.38	370.17	4367.15	227.70	3.13	36.98	1.93	13.76	72.65	18.40	
Marsh Mat	15	11.26	13.70	-28.82	-6.67	360.75	4647.39	375.33	3.21	41.29	3.33	15.03	66.54	28.50	
Marsh Mat	30	11.30	12.47	-29.08	-7.38	393.68	4676.80	253.28	3.48	41.38	2.24	13.86	72.15	19.11	
Marsh Mat	45	11.18	12.33	-29.03	-8.29	371.42	4497.30	343.51	3.32	40.24	3.07	14.13	70.79	26.96	
Marsh Mat	60	11.22	13.42	-29.32	-10.45	388.92	4358.16	270.00	3.47	38.86	2.41	13.07	76.49	21.87	
Marsh Mat	75	10.81	12.39	-28.94	-5.27	304.53	3632.80	263.49	2.82	33.61	2.44	13.92	71.85	25.60	
Marsh Mat - R	75	11.81	12.36	-28.93	-5.06	326.00	3941.24	281.23	2.76	33.36	2.38	14.10	70.90	25.18	
SU06															
P. virgatum	15	11.85	6.40	-27.91	-7.99	210.37	5078.42	55.00	1.78	42.86	0.46	28.16	35.51	3.82	107.66
P. virgatum	15	10.76	6.02	-28.32	-8.64	185.69	4752.64	55.89	1.73	44.19	0.52	29.86	33.49	4.15	123.94
P. virgatum	30	11.40	7.21	-29.20	-8.75	94.50	4727.02	39.33	0.83	41.47	0.35	58.36	17.14	2.94	171.39
P. virgatum	30	11.04	7.33	-28.54	-8.28	95.62	4556.44	32.31	0.87	41.29	0.29	55.59	17.99	2.50	139.13
P. virgatum	60	11.89	6.27	-28.61	-6.43	183.66	4856.07	28.23	1.54	40.83	0.24	30.85	32.42	2.05	63.29
P. virgatum	60	11.20	4.77	-28.35	-6.52	195.41	4650.30	37.98	1.74	41.52	0.34	27.76	36.02	2.88	80.04
P. virgatum	100	10.81	12.59	-30.64	-1.88	218.07	4269.13	35.05	2.02	39.50	0.32	22.84	43.78	2.90	66.18
P. virgatum	100	11.72	12.47	-30.58	-2.44	238.85	4777.94	50.49	2.04	40.78	0.43	23.34	42.85	3.73	87.05
P. virgatum	200	11.99	4.08	-30.38	-7.29	323.19	4900.44	43.48	2.69	40.86	0.36	17.69	56.53	3.13	55.40
P. virgatum	200	11.35	3.95	-30.36	-7.53	311.75	4704.79	39.67	2.75	41.45	0.35	17.61	56.80	2.98	52.40
P. virgatum	200	10.39	4.28	-30.19	-4.89	216.43	4397.29	29.42	2.08	42.34	0.28	23.70	42.19	2.36	55.97
H. umbellata	15	11.40	9.28	-26.88	-8.14	169.23	4264.30	9.40	1.48	37.39	0.08	29.40	34.02	0.78	22.87
H. umbellata	15	11.56	9.30	-26.73	-8.13	170.97	4297.43	8.89	1.48	37.18	0.08	29.33	34.10	0.73	21.41
H. umbellata	15	10.52	8.95	-26.67	-5.67	155.72	3826.68	8.54	1.48	36.39	0.08	28.67	34.88	0.79	22.58
H. umbellata	30	11.44	7.97	-26.55	-10.33	125.30	4777.19	10.06	1.09	41.75	0.09	44.48	22.48	0.74	33.07
H. umbellata	30	11.08	8.18	-26.86	-12.59	128.06	4305.14	9.11	1.16	38.86	0.08	39.22	25.50	0.75	29.31
H. umbellata	60	10.52	3.89	-26.67	-6.69	221.66	3824.03	13.46	2.11	36.34	0.13	20.13	49.69	1.24	25.00
H. umbellata	60	11.14	4.09	-26.66	-6.52	263.68	4226.62	11.71	2.37	37.95	0.11	18.70	53.47	0.98	18.29
H. umbellata	300	10.05	23.99	-27.52	-0.47	272.35	3723.22	17.09	2.71	37.06	0.17	15.95	62.70	1.62	25.83
H. umbellata	300	10.39	24.96	-27.94	-1.22	238.47	3766.33	15.88	2.29	36.24	0.15	18.43	54.27	1.49	27.43
Marsh Mat	15	8.00	9.95	-28.29	-8.92	242.05	2820.39	148.00	3.03	35.25	1.85	13.59	73.56	18.52	251.78
Marsh Mat	30	7.92	11.93	-29.11	-7.58	277.16	3374.89	136.39	3.50	42.60	1.72	14.21	70.39	14.26	202.63
Marsh Mat	60	7.24	11.94	-29.16	-11.76	237.70	2955.26	233.76	3.28	40.80	3.23	14.50	68.94	27.92	404.94
Marsh Mat	100	6.72	17.81	-28.75	-3.25	187.45	2649.61	163.69	2.79	39.42	2.44	16.49	60.64	21.80	359.57
Marsh Mat	200	6.83	16.85	-29.19	-5.43	167.39	2935.65	79.76	2.45	42.97	1.17	20.46	48.87	9.59	196.21
Marsh Mat	300	7.21	13.51	-28.25	-0.18	153.48	2499.70	97.13	2.13	34.66	1.35	19.00	52.63	13.71	260.59
P. virgatum	0	11.89	-2.12	-27.75	0.34	375.55	4645.75	43.71	3.16	39.08	0.37	14.43	69.29	3.32	50.92
P. virgatum	15	5.62	7.98	-25.83	-4.37	167.03	2104.06	25.41	2.97	37.47	0.45	14.70	68.04	4.26	66.55
P. virgatum	30	9.64	3.52	-26.44	-3.42	126.85	3509.22	26.81	1.32	36.41	0.28	32.28	30.98	2.70	92.48
P. virgatum	45	11.78	-0.46	-28.02	-2.55	244.46	5142.60	33.67	2.08	43.67	0.29	24.54	40.74	2.31	60.27
P. virgatum	75	10.47	3.75	-27.63	-2.54	219.64	4533.44	27.28	2.10	43.31	0.26	24.08	41.53	2.12	54.33
P. virgatum	100	10.74	10.63	-27.11	-0.23	220.22	3670.26	13.62	2.05	34.17	0.13	19.44	51.43	1.31	27.05
H. umbellata	150	11.24	28.62	-29.25	-2.35	234.09	4011.26	11.77	2.08	35.69	0.10	19.99	50.02	1.04	22.01
H. umbellata	200	10.59	14.85	-27.19	-1.24	173.93	3657.54	10.10	1.64	34.55	0.10	24.53	40.76	0.97	25.41
H. umbellata	250	10.15	21.53	-29.21	-1.81	242.68	3759.59	14.65	2.39	37.03	0.14	18.07	55.33	1.38	26.41
H. umbellata	275	11.97	17.52	-31.06	-0.28	402.28	4985.83	45.79	3.36	41.67	0.38	14.46	69.16	3.24	49.80
H. umbellata	300	11.31	18.04	-25.84	0.00	415.55	4525.87	26.51	3.68	40.03	0.23	12.71	78.70	2.07	27.91
H. umbellata	400	10.04	17.32	-28.95	-8.32	273.12	3826.95	21.87	2.72	38.11	0.22	16.35	61.17	2.02	35.04
H. umbellata	800	12.10	15.95	-28.28	-13.52	215.22	4774.46	43.80	1.78	39.45	0.36	25.88	38.64	3.24	89.03

Marsh Mat* - Refers to the bulk dead material of the floating marsh.

APPENDIX D – SITE PHOTOGRAPHY

Plate 1. February 2005

Plate 2. April 2007


Plate 3. June 2005

Plate 4. January 2006

VITA

Caleb Izdepski is a native of New Orleans, Louisiana. While working on towards a bachelor's in biology from Louisiana State University, Caleb volunteered extensively with a nonprofit humanitarian organization based in Southern Louisiana. Through his work with this organization, Caleb found first hand while vastly different cultural, geographic, and economic conditions are seen they are all joined by the same underlying principles. While working on the Master of Science degree, Caleb become increasingly involved in both photojournalism and water quality in the developing world. His long-term interests involve international health as it relates to water quality and sustainability in developing countries. Caleb began his graduate work in water quality at LSU in the context of wetland restoration and ecosystem function.